FRA Step 4
Tree and Shrub Species Selection for Reforestation of Reclaimed Mineland

Ron Rathfon, Extension Forester
Purdue University
Reclamation mid 20th century:

- Reclamation synonymous with reforestation
- 1941 state law required tree planting
Reclamation mid 20th century:
- Early studies focused on species trials
Historical Perspective

- Reclamation later in the 20th century:
  - 1967, Indiana 1st state to require grading and contouring
  - 1977, SMCRA
  - 1980’s, difficulty establishing and maintaining tree plantings
  - Many operators opted to reclaim to “higher and better uses.”

Photo: Tim Taylor
Reclaimed mine conditions pre-FRA

Relative importance of site factors different on mined vs. native sites.

• Compaction
• Poor internal drainage
• High soluble salt level
• Aggressive ground covers

Novel Site Conditions

Limited species selection
Reclaimed mine conditions on FRA

Relative importance of site factors different on mined vs. native sites.

- Improved rooting depth
- Improved soil texture and internal drainage
- Optimal pH
- Tree-compatible ground cover

Sometimes improved over prior natural site conditions

Expanded species selection
4. Plant two types of trees - early succession species for wildlife and soil stability, and commercially valuable crop trees.
Species Selection Factors

- Bond release
- Site/adaptation
- Seed Source
- Succession
- Nurse species
- Species compatibility
- Landscape considerations
- Long-term forest health
- Deer
- Planting stock availability
- Long-term landowner objectives
- Exotic species
Bond Release

- 450 living trees and shrubs per acre at bond release
- Long term success
  - Healthy stand
  - Acquiring attributes and functions of natural forest
  - Likely to produce wood products
  - Likely to produce environmental amenities ascribed to forest
Site

The sum total of the effects of all the factors of a location on the reproduction, establishment, growth, decline, and death of the trees and forest of that location.
Site Factors

CLIMATE
- radiation, air temperature, rainfall, relative humidity, fog, wind, lightening, fire, etc.

TOPOGRAPHY
- physiography, aspect, slope

SOIL
- texture, structure, pH, ground water, temperature, minerals, organic matter, etc.

BIOTIC FACTORS
- associated plants, animals above and below soil, humans

Factors Directly Available to Trees

LIGHT
- As source of energy for photosynthesis

HEAT
- As energy for metabolic processes

WATER
- Maintains cell function, component in photosynthesis, and transports nutrients

CHEMICAL FACTORS
- CO₂, O₂, pH, pollutants, nutrients, allelopathic compounds

MECHANICAL FACTORS
- Damage through wind, fire, snow, animals

Climate

Southern Red Oak

Quaking Aspen
Topography

Aspect

N: Cool Moist
S: Hot Dry
Topography

Slope

\[ \frac{\text{Rise}}{\text{Run}} \times 100 = \% \text{ slope} \]

- Deeper topsoil
- More water infiltration

- Thinner topsoil
- Less water infiltration

Low erosion

High erosion

Tree illustration showing root systems associated with different slope conditions.
Topography

Aspect - Slope

deep soil, cool, moist
shallow soil, hot, dry
Topography

Position

- ridgetop
- shoulder
- sideslope
- toeslope or cove
- bottom
Topography

Virginia (southern Appalachia)

Soil Texture

Sand
Silt
Clay

Sandy loam (moisture deficient)
Clay loam
Heavy clay (aeration deficient)
Soil Profile

Layers

Depth

Soil Classification

Hydrologic Classification

Soil Moisture

Zone of Aeration

Intermediate Zone

Water Table

Groundwater

Zone of Saturation

Bedrock (Often fractured)
Soil

Spoil or Growth Medium

- Alkaline: pH 6.5-8.5
  - shales and siltstones
  - bur oak
  - sycamore
  - hybrid poplar
  - sugar maple

- Acid: pH 4.5-6.5
  - sandstone
  - Virginia pine
  - pitch x loblolly pine
  - All native hardwoods & conifers
    - e.g.: red, white, black oaks
    - sugar maple
    - white ash
    - tulip poplar
    - black cherry

Site:

1. Dry (xeric)
2. Moist (mesic)
3. Wet (hydric)
Dry (xeric)
Limiting factor: Moisture (lack of)

Results from:
1. South aspect
2. Shallow and/or sandy soil

Forest characterized by:
1. Drought tolerant
2. Slow growth
3. Lower stocking
4. Low quality timber
Moist (mesic)
Limiting factor:
Light

Results from:
1. North aspect
2. Deep, moisture accumulating and retentive soil (not wet)
Moist (mesic)

Forest characterized by:
1. Moisture and nutrient demanding trees
2. Fast growth
3. High stocking
4. Good quality timber
Wet (hydric)
Limiting factor: Moisture (too much)

Results from:
1. Frequent, semi-permanent, or permanent flooding
2. High water table
3. Restrictive layer

Patoka River - oxbow
Site

Wet (hydric)

Forest characterized by:
1. Flood tolerant trees
2. Shallow rooted
3. Fast to slow growth
4. High to low stocking
5. Good to poor quality timber

Pumpkin Ash
Buffalo Flats, Jasper
Contribute to local economy
Community and environmental asset
Seed Source

Northern Red Oak

Latitude

Elevation
Forest Succession

Three major stages
1. Pioneer
2. Intermediate/Transitional/Subclimax
3. Climax
Forest Succession

Pioneer
Forest Succession

Pioneer

Species Characteristics:
1. Seed light, windblown, waterborn, or transported by birds
2. Require full sunlight – shade intolerant
3. Fast growing
4. Cannot reproduce in own shade
Forest Succession

Intermediate (transitional, subclimax)
Climax

1. Shade tolerant
2. Slower growing
3. Can reproduce in own shade
<table>
<thead>
<tr>
<th>Habitat</th>
<th>Pioneer</th>
<th>Transitional</th>
<th>Climax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>Aspen, sassafras, cedar, Virginia pine</td>
<td>Oak, hickory</td>
<td></td>
</tr>
<tr>
<td>Mesic</td>
<td>Many, tulip, cherry, aspen, sassafras</td>
<td>Oak, hickory, ash, elm, walnut</td>
<td>Beech, maple, basswood</td>
</tr>
<tr>
<td>Wet (bottomland)</td>
<td>Ash, cottonwood, boxelder, willow, sycamore</td>
<td>Sycamore, silver maple, hackberry, bur oak, swamp white oak, American elm, ash</td>
<td></td>
</tr>
</tbody>
</table>
Accelerate Succession

Land stabilization and erosion control

Bond release

Economic returns to land owner

Nurse Species

Improve site conditions and crop tree growth and quality

N - fixing

Shade/cooling

Train

Contribute to bond release

Early successional

Compatible with crop trees

Wildlife
Species Compatibility

- Successional status
- Growth rate
- Longevity
Species Compatibility

Monocultures vs. Mixed Stands
Natural seed sources

Yellow-poplar – 300,000 to 600,000 seed/acre up to 600 feet.

Cottonwood – 48 million seeds on one tree, 100’s of feet to miles.

vs.

heavy-seeded species
Indiana mines reclaimed 1988 - 1995
- Over 86% of sites dominated by two tree species
- B. locust most abundant species on 15 of 22 sites.
Black Locust

Black locust borer
*Megacyllene robinia*
Trees under stress
most susceptible
Monocultures or single-species dominated stands at greater risk of catastrophic loss and long-term chronic health problems.

In 1999, IN Div. Reclamation issued recommendation to limit black locust to 25% of stand stocking.
Emerald Ash Borer
Deer

Oak –

Yum, Yum!
Planting Stock Availability

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>ORDER CODE</th>
<th>PRICE PER 100 SEEDLINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONIFER SEEDLINGS - 3 YEAR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WHITE PINE 3-0</td>
<td>8</td>
<td>$35.25</td>
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<tr>
<td>CONIFER SEEDLINGS - 1 &amp; 2 YEAR</td>
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<td></td>
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<tr>
<td>TAMARACK 2-0</td>
<td>15</td>
<td>$26.05</td>
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<tr>
<td>NORWAY SPRUCE 2-0</td>
<td>38</td>
<td>$26.05</td>
</tr>
<tr>
<td>VIRGINIA PINE 1-0</td>
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<td>$26.05</td>
</tr>
<tr>
<td>PITCH x Loblolly Pine 2-1-0</td>
<td>31</td>
<td>$26.05</td>
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<td></td>
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<tr>
<td>DECIDUOUS TREE SEEDLINGS - 1 YEAR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLACK CHERRY 1-0</td>
<td>43</td>
<td>$31.00</td>
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<tr>
<td>BLACK GUM 1-0</td>
<td>43</td>
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<tr>
<td>BLACK LOCUST 1-0</td>
<td>44</td>
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<tr>
<td>BLACK WALNUT 1-0</td>
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<tr>
<td>BUR OAK 1-0</td>
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<td>CHERRYBARK OAK 1-0</td>
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<td>CHESTNUT OAK 1-0</td>
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<td>PECAN 1-0</td>
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<tr>
<td>PERSIMMON 1-0</td>
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<td>PIN OAK 1-0</td>
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<td>RED OAK 1-0</td>
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<tr>
<td>RIVER BIRCH 1-0</td>
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<tr>
<td>SILVER MAPLE 1-0</td>
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<td>SWAMP CHESTNUT OAK 1-0</td>
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<td>SWAMP WHITE OAK 1-0</td>
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<td>SWEETGUM 1-0</td>
<td>73</td>
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<td>SYCAMORE 1-0</td>
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<td>TULIPTREE 1-0</td>
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<td>WHITE OAK 1-0</td>
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<td>OVERCUP OAK 1-0</td>
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<tr>
<td>WHITE BIRCH 1-0</td>
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<tr>
<td>CHESTNUT OAK 1-0</td>
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<td>$31.00</td>
</tr>
<tr>
<td>KENTUCKY COFFEE TREE 1-0</td>
<td>92</td>
<td>$31.00</td>
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<tr>
<td>DECIDUOUS TREE SEEDLINGS - 2 YEAR</td>
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<tr>
<td>BUR OAK 2-0</td>
<td>108</td>
<td>$37.55</td>
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<tr>
<td>PECAN 2-0</td>
<td>118</td>
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<td>RED OAK 2-0</td>
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<td>WHITE OAK 2-0</td>
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<tr>
<td>SHAGBARK HICKORY 2-0</td>
<td>144</td>
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<tr>
<td>SUGAR MAPLE 2-0</td>
<td>145</td>
<td>$37.55</td>
</tr>
<tr>
<td>RED MAPLE 2-0</td>
<td>147</td>
<td>$37.55</td>
</tr>
<tr>
<td>SHELLBARK HICKORY 2-0</td>
<td>189</td>
<td>$37.55</td>
</tr>
</tbody>
</table>

* Species short supply

Information concerning the mature size and recommended use of these species can be obtained by contacting either nursery or from the "Tree Species Information" on our website at www.dnr.in.gov/forestry
Landowner Objectives

Contribute to local economy
Community and environmental asset
Exotics

Invasive threat!
**General Prescriptions**

**Region:** Midwest coal fields (The Illinois Coal Basin located in southern Indiana, southern Illinois, and western Kentucky)

**Site Type:** Moderately to steeply sloped upland

<table>
<thead>
<tr>
<th>Forest Types</th>
<th>Long Term Benefits</th>
<th>Primary Forest Canopy Species</th>
<th>Secondary Forest Canopy Species</th>
<th>Nurse Species</th>
<th>Wildlife Species</th>
<th>Planting Design Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak-hickory</td>
<td>Woodland wildlife food and cover</td>
<td>Oak: black, red, white</td>
<td>Oak: bur, chestnut, chinkapin, scarlet</td>
<td>Pine: Virginia (south), pitch x loblolly hybrid, shortleaf (south), red (north)</td>
<td>serviceberry</td>
<td>American plum, Jersey-tea, southern blackhaw, persimmon, flowering dogwood, hawthorns, crabapple, huckleberry, blueberry, redbud</td>
</tr>
<tr>
<td></td>
<td>Low grade to high grade sawtimber</td>
<td>Hickory: pignut, shagbark</td>
<td>American chestnut, black gum</td>
<td>bristly locust</td>
<td>black locust</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carbon sequestration</td>
<td>red maple</td>
<td>yellow-poplar</td>
<td>black locust</td>
<td>red cedar</td>
<td></td>
</tr>
</tbody>
</table>

**Forest Productivity Level:** low to medium (site index: 65 - 70 ft.)

**Site Condition:** dry to moist

Aspect: southeast and northwest; Landscape Position: upper-, mid-, and lower- and slopes; Slope: > 10%; Soil Depth: 2 – 4 ft.; Soil Drainage: well-drained; Soil Texture: sandy loam to silt loam.
**General Prescriptions**

**Region:** Midwest coal fields (The Illinois Coal Basin located in southern Indiana, southern Illinois, and western Kentucky)

**Site Type:** Moderately to steeply sloped upland

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<th>Wildlife Species</th>
<th>Planting Design Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed oak</td>
<td>High grade sawtimber and veneer</td>
<td>oak: red, white, yellow-poplar, black cherry, black walnut</td>
<td>oak: black, chinkapin, white ash</td>
<td>Pine: white, black alder, bristly locust, black locust</td>
<td>hazelnut, spicebush, hawthorn (native), American plum, flowering dogwood, gray dogwood, blackhaw arrowwood, crabapple, persimmon, redbud</td>
<td>Plant white ash at low rates, &lt; 50 per acre, due to emerald ash borer.</td>
</tr>
<tr>
<td>Poplar-ash-cherry</td>
<td>Forest wildlife</td>
<td>Mixed hardwoods</td>
<td>Carbon sequestration</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Forest Productivity Level:** high (northern red oak site index > 70 ft.)  
**Site Condition:** Moist  
**Aspect:** northwest to east; **Landscape Position:** lower, concave slopes, coves; **Slope:** >10%; **Soil Depth:** > 4 ft.; **Soil Drainage:** well-drained to moderately well-drained; **Soil Texture:** loam to silt loam

- Black walnut for timber production should only be planted on the most nutrient rich sites with the deepest, well-drained soils.
- Plant fast growing yellow-poplar, black cherry, and white ash together in blocks separate from slower growing oaks.
- Black walnut for timber production should only be planted on the most nutrient rich sites with the deepest, well-drained soils.
### General Prescriptions

**Region:** Midwest coal fields (The Illinois Coal Basin located in southern Indiana, southern Illinois, and western Kentucky)

**Site Type:** Flat bottomland and riparian

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<th>Nurse Species</th>
<th>Wildlife Species</th>
<th>Planting Design Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardwood swamps</td>
<td>Woodland wildlife food and cover</td>
<td>Oak: overcup swamp white, swamp chestnut, <em>pin</em></td>
<td>ash: green, pumpkin maple: red, silver sycamore <em>river birch</em>, <em>sweet gum</em> baldcypress</td>
<td>cottonwood swamp cottonwood hybrid poplar</td>
<td>buttonbush dogwood: silky, red osier deciduous holly speckled alder shrub willows</td>
<td>Plant ash at low rates, &lt; 50 per acre, due to emerald ash borer. Most bottomland trees and shrubs cannot establish in permanent standing surface water.</td>
</tr>
<tr>
<td>Cypress swamps</td>
<td>Low grade sawtimber, pallet stock, ties, mine props</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Site Condition:** wet bottomland flat

Forest Productivity Level: low  
Soil Depth: <2 ft.; Soil Drainage: poorly drained with permanent high water table and seasonal flooding; Soil Texture: silty clay to clay and/or compacted layer within 2 ft.
## General Prescriptions

**Region:** Midwest coal fields (The Illinois Coal Basin located in southern Indiana, southern Illinois, and western Kentucky)

**Site Type:** Flat bottomland and riparian

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<th>Secondary Forest Canopy Species</th>
<th>Nurse Species</th>
<th>Wildlife Species</th>
<th>Planting Design Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottomland Oak-hickory</td>
<td>High grade sawtimber wildlife</td>
<td>oak: swamp white, swamp chestnut, bur, cherrybark, shumard shellbark hickory cottonwood hybrid poplar</td>
<td>green ash maple: red, silver sycamore river birch sweet gum</td>
<td>black alder black willow honeylocust</td>
<td>hazelnut spicebush hawthorn (native) dogwood: gray, silky, red osier deciduous holly</td>
<td>An elevation change of 2 – 4 ft. in river bottoms can change the hydrology of the soil from well-drained to wet. These sometimes subtle changes should be noted and species matched accordingly. Plant green ash at low rates, &lt; 50 per acre, due to emerald ash borer.</td>
</tr>
<tr>
<td>Industrial plantation</td>
<td>Carbon sequestration Biomass /bioenergy and pulpmill feedstock</td>
<td>green ash maple: red, silver sycamore</td>
<td>black alder black willow honeylocust</td>
<td>hazelnut spicebush hawthorn (native) dogwood: gray, silky, red osier deciduous holly</td>
<td>American cranberry bush</td>
<td></td>
</tr>
</tbody>
</table>
# West Virginia

## MOISTURE REGIME

<table>
<thead>
<tr>
<th>Wet</th>
<th>Moist - Moderate</th>
<th>Moderate</th>
<th>Moderate - Dry</th>
<th>Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

### TREES

- **White Ash**
  - Wet: White Ash
  - Moist - Moderate: White Ash
  - Moderate: White Ash
  - Moderate - Dry: Chestnut Oak
  - Dry: Black Oak
- **Yellow Poplar**
  - Wet: White Oak
  - Moist - Moderate: White Oak
  - Moderate: White Oak
  - Moderate - Dry: Chestnut Oak
  - Dry: Black Oak
- **Sycamore**
  - Wet: N. Red Oak
  - Moist - Moderate: N. Red Oak
  - Moderate: Black Oak
  - Moderate - Dry: Scarlet Oak
  - Dry: Scarlet Oak
- **Black Willow**
  - Wet: Black Cherry
  - Moist - Moderate: Black Cherry
  - Moderate: Chestnut Oak
  - Moderate - Dry: Native Hickories
  - Dry: Scarlet Oak
- **Black Walnut**
  - Wet: Sugar Maple
  - Moist - Moderate: Sugar Maple
  - Moderate: Black Cherry
  - Moderate - Dry: Scarlet Oak
  - Dry: Native Hickories
- **Butternut**
  - Wet: Yellow Poplar
  - Moist - Moderate: Yellow Poplar
  - Moderate: Native Hickories
  - Moderate - Dry: Red Maple
  - Dry: Red Maple
- **Silver Maple**
  - Wet: Black Walnut
  - Moist - Moderate: Black Walnut
  - Moderate: Yellow Poplar
  - Moderate - Dry: Black Locust
  - Dry: Norway Spruce
- **Red Maple**
  - Wet: Cucumbertree
  - Moist - Moderate: Cucumbertree
  - Moderate: Big-tooth Aspen
  - Moderate - Dry: Virginia Pine
  - Dry: Virginia Pine
- **American Beech**
  - Wet: Basswood
  - Moist - Moderate: Basswood
  - Moderate: Quaking Aspen
  - Moderate - Dry: Quaking Aspen
  - Dry: Quaking Aspen
- **River Birch**
  - Wet: Black Locust
  - Moist - Moderate: Black Locust
  - Moderate: Red Maple
  - Moderate - Dry: Sweet Birch
  - Dry: Sweet Birch
- **Persimmon**
  - Wet: Red Maple
  - Moist - Moderate: Red Maple
  - Moderate: Red Maple
  - Moderate - Dry: Sweet Gum
  - Dry: Sweet Gum
- **Eastern Hemlock**
  - Wet: Butternut
  - Moist - Moderate: Butternut
  - Moderate: Big-tooth Aspen
  - Moderate - Dry: White pine
  - Dry: White pine
- **Quaking Aspen**
  - Wet: American Beech
  - Moist - Moderate: American Beech
  - Moderate: Quaking Aspen
  - Moderate - Dry: White pine
  - Dry: White pine
- **Black Willow**
  - Wet: Persimmon
  - Moist - Moderate: Persimmon
  - Moderate: Short-leaf Pine
  - Moderate - Dry: Native Hickories
  - Dry: Native Hickories
- **Silver Maple**
  - Wet: Red Mulberry
  - Moist - Moderate: Red Mulberry
  - Moderate: Black Alder
  - Moderate - Dry: Black Alder
  - Dry: Black Alder
- **Persimmon**
  - Wet: Black Willow
  - Moist - Moderate: Black Willow
  - Moderate: Sweet Gum
  - Moderate - Dry: Norway Spruce
  - Dry: Norway Spruce

### SHRUBS

- **Black Alder**
  - Wet: Black Alder
  - Moist - Moderate: Black Alder
  - Moderate: Flowering Dogwood
  - Moderate - Dry: Flowering Dogwood
  - Dry: Flowering Dogwood
- **Eastern Red Bud**
  - Wet: Eastern Red Bud
  - Moist - Moderate: Eastern Redbud
  - Moderate: Eastern Redbud
  - Moderate - Dry: Black Alder
  - Dry: Black Alder
- **Red Mulberry**
  - Wet: Red Mulberry
  - Moist - Moderate: Red Mulberry
  - Moderate: Black Alder
  - Moderate - Dry: Gray Dogwood
  - Dry: Gray Dogwood
- **Crab Apple**
  - Wet: Crab Apple
  - Moist - Moderate: Crab Apple
  - Moderate: Crab Apple
  - Moderate - Dry: Gray Dogwood
  - Dry: Gray Dogwood
- **American Holly**
  - Wet: American Holly
  - Moist - Moderate: Crab Apple
  - Moderate: Gray Dogwood
  - Moderate - Dry: Gray Dogwood
  - Dry: Gray Dogwood
- **Hawthorn**
  - Wet: Hawthorn
  - Moist - Moderate: Gray Dogwood
  - Moderate: Gray Dogwood
  - Moderate - Dry: Gray Dogwood
  - Dry: Gray Dogwood
Stand Stocking

Understocked

Well stocked
Field Application

- Map
- Reclamation forester
- Close field supervision